The HD-DCM-Lite: a High-Dynamic DCM with Extended Scanning Capabilities for Sirius/LNLS Beamlines

LNLS Brazilian Synchrotron Light Laboratory · sirius
CNPEM Brazilian Center for Research in Energy and Materials

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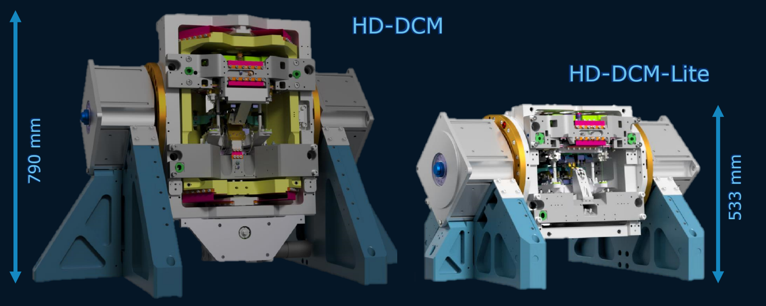
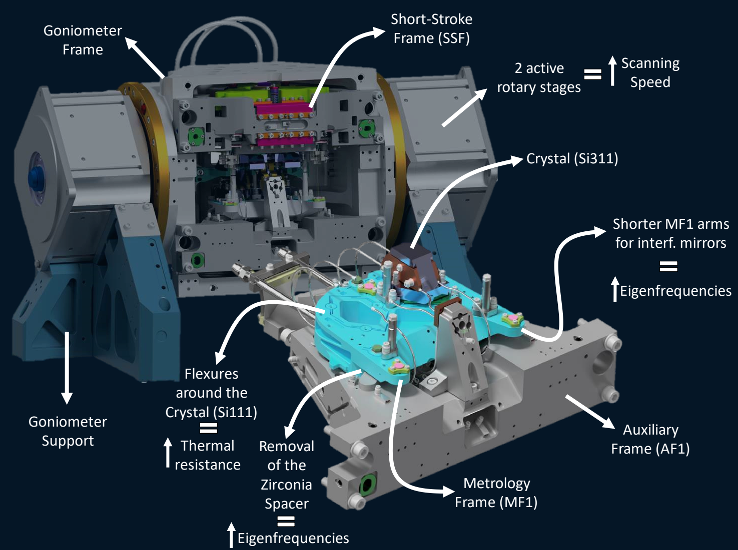
Abstract

After successfully designing, installing, and commissioning two units of the High-Dynamic Double-Crystal Monochromator (HD-DCM) at the Brazilian Synchrotron Light Laboratory (LNLS) - Sirius, two more units are now required. Since they demand only a smaller energy range (5 to 35 keV), the total gap stroke of the new instruments can be significantly reduced, creating an opportunity to adapt the existing design towards the so-called HD-DCM-Lite. Removing the large gap adjustment mechanism allows a reduction of the main inertia by a factor of 5, enabling the HD-DCM-Lite to deliver energy flyscans of hundreds of eV reaching 20 cycles per second, while keeping fixed exit and the pitch stability in the range of 10 nrad RMS (1 Hz - 2.5 kHz). Hence, an unparallel bridge between slow step-scan DCMs and fast channel-cut monochromators is created. This work presents the in-house development of the HD-DCM-Lite, focusing on its mechanical design, discussions on the ultimate scanning constraints (rotary stage torque, voice-coil forces, interferometers and encoders readout speed limits and subdivisional errors), and thermal management.



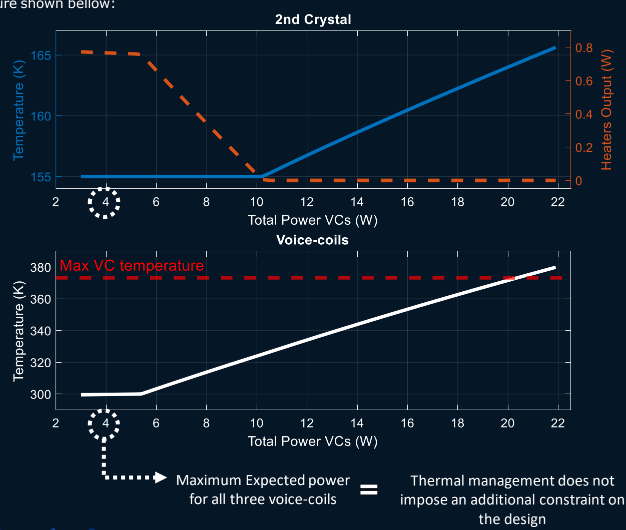
Mechanical Design

The design of the original HD-DCM [1-3] had to be adapted to become capable of meeting the fast energy scan requirements for quick-EXAFS experiments that will take place at the QUATI (quick absorption spectroscopy) beamline. The figure bellow summarizes the main modifications towards the HD-DCM-Lite:



Thermal Management

A Simulink® lumped-mass thermal model was developed to guarantee the thermal management of the HD-DCM-Lite, allowing to obtain the desired braid specifications [4] for the second crystals (CR2s), and to make a sensitivity study of the voice-coils power output influence on the CR2s working temperature shown bellow:



Conclusion

The predictive design methodology that successfully conceived the HD-DCM is now applied in the development of the HD-DCM-Lite for extended scanning capabilities while maintaining ultra-high stability performance. The competences in design and control, together with toolboxes and libraries, that were developed over the first project have allowed the new machine to be completely designed in-house at LNLS in a short time scale. The prototype is expected to start to be tested still in 2021.

Acknowledgments

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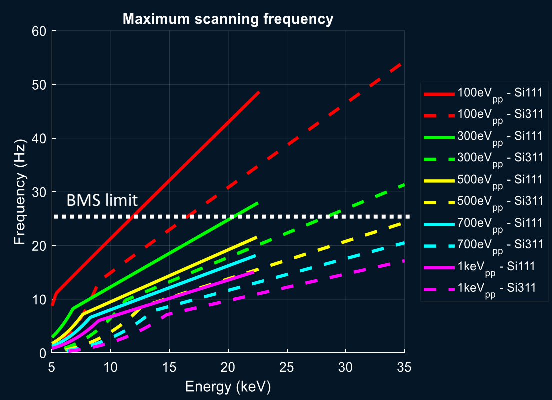
Scanning Constraints

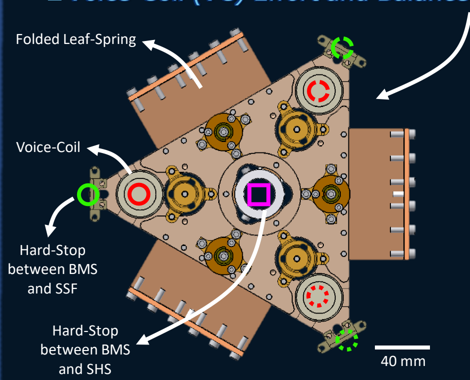
For time-resolved experiments, faster energy scans may enable scientific opportunities in analyzing quick chemical reactions or material phase variations, for example. Here are presented the main factors that constrain the HD-DCM-Lite scanning speed:

Torque, Encoder and Interferometer Constraints:



The graphic above shows how rotary stages torque, its encoder and the gap control interferometers limitations impact the system scanning speed, stating boundary curves for each crystal set, central energy and peak-to-peak energy amplitude. For low energies, the interferometer is the main constraint (non-linear in energy), whereas torque (linear in energy) limits the higher frequencies. Scanning frequencies above the curves cannot be performed.

Voice-Coil (VC) Effort and Balance-Mass (BMS) Limits:



Contributions:

- Misalignment: worst case of 3 mrad between the SHS and the MF1.
- Scan: worst root mean square (RMS) value due to scanning trajectories.
- Gap Offset: effect of the worst SHS position inside its range.

Contributions	F_{VC1} [N]	F_{VC2} [N]	F_{VC3} [N]	d_{V1} [mm]	d_{V2} [mm]	d_{V3} [mm]	d_{rel} [mm]	θ_{rel} [mrad]
Misalignment	1.3	3.8	3.8	<0.1	<0.1	<0.1	-	3.0
Scan (RMS)	0.3	3.1	3.1	0.8	0.8	0.8	0.8	0.8
Gap Offset	3.1	3.1	3.1	0.1	0.1	0.1	1.4	-
TOTAL	**4.7**	**8.0**	**8.0**	**0.9**	**0.9**	**0.9**	**2.2**	**3.8**

Do not add new scanning constraints (columns F_{VC1} to d_{V3})

Limits the scanning frequencies at 24 Hz (columns d_{rel} and θ_{rel})

References

[1] R. R. Geraldes, et al., "The new high dynamics DCM for Sirius", in Proc. MEDSI 2016, Barcelona, Spain, Sep. 2016.
[2] R. R. Geraldes, et al., "The status of the new High-Dynamic DCM for Sirius," in Proc. MEDSI 2018, Paris, France, June 2018.
[3] R. R. Geraldes, et al. "Dynamic error budgeting in the development of the High-Dynamic Double-Crystal Monochromator at Sirius Light Source." Proc. ASPE Topical Meeting 2020, Boston, USA, May 2020.
[4] F. R. Lena *et al.* "Copper Braid Heat Conductors for Sirius Cryogenic X-Ray Optics". Presented at MEDSI 2020, Chicago, USA, this conference.

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